CHM113 General Chemistry I

Key

Limiting Reagents & Percent Yield Practice Problems

1) Titanium which is used to make airplane engines and frames, can be obtained indirectly from the following process:

$$3\ TiO_2\ (s) + 4\ C\ (s) + 6\ Cl_2\ (g) \rightarrow 3\ TiCl_4\ (g) + 2\ CO_2\ (g) + 2\ CO\ (g)$$

want in grams

4.15 g 5.67 g 6.78 g

A vessel contains 4.15 g TiO_2, 5.67 g C, and 6.78 g Cl_2. How many grams of $TiCl_4$ can be produced?

* need to determine limiting reactant (An alternative way that what we discussed in class is to calculate moles of product & compare (shown below))

$$4.15\ g\ TiO_2 \times \frac{1\ mol\ TiO_2}{79.866\ g\ TiO_2} \times \frac{3\ mol\ TiCl_4}{3\ mol\ TiO_2} = 0.05196 = 0.0520\ mol\ TiCl_4$$

molar mass TiO_2 = 1(Ti) + 2(O)
= 1(47.867 g/mol) + 2(15.4994 g/mol)
= 79.866 g/mol

-or- Like in class 1) moles 2) molar ratios w/ other reactants

0.0520 mol TiO_2 → w/ C, w/ Cl_2
0.472 mol C → w/ TiO_2, w/ Cl_2
0.0956 mol Cl_2 → w/ C & w/ TiO_2

This is a lot of #s so sometimes easier to convert to the same product & compare that way

$$5.67\ g\ C \times \frac{1\ mol\ C}{12.0107\ g\ C} \times \frac{3\ mol\ TiCl_4}{4\ mol\ C} = 0.354\ mol\ TiCl_4$$

from P.T.

$$6.78\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.9054\ g\ Cl_2} \times \frac{3\ mol\ TiCl_4}{6\ mol\ Cl_2} = 0.0478\ mol\ TiCl_4$$

* smallest # (produced least amount of product) ∴ limiting reactant is Cl_2

molar mass = 2(Cl) = 2(35.4527 g/mol)
= 70.9054 g/mol

want: mass $TiCl_4$ produced from limiting reagent

$$0.0478\ mol\ TiCl_4 \times \frac{189.678\ g\ TiCl_4}{1\ mol\ TiCl_4}$$

molar mass $TiCl_4$ = (1)(Ti) + 4(Cl) = 1(47.867 g/mol) + 4(35.4527 g/mol) = 189.678 g/mol $TiCl_4$

mass $TiCl_4$ produced = $0.0478\ mol\ TiCl_4 \times \frac{189.678\ g\ TiCl_4}{1\ mol\ TiCl_4}$ = **9.06 g $TiCl_4$**

2) Aspirin, $C_9H_8O_4$ is prepared by heating salicylic acid, $C_7H_6O_3$, with acetic anyhydride, $C_4H_6O_3$. The other product is acetic acid, $C_2H_4O_2$. Consider when 2.00 g salicylic acid is heated with 4.00 g acetic anhydride.

* Note: on an exam I would give you the states of matter of these

a) What is the limiting reagent?

Know

$$C_7H_6O_3(s) + C_4H_6O_3(l) \longrightarrow C_9H_8O_4(s) + C_2H_4O_2(l)$$ ✓ Balanced as is

S.A. = salicylic acid — 2.00 g — molar mass 138.1200 g/mol

acetic anhydride = A.A. — 4.00 g — molar mass 102.0900 g/mol

aspirin — molar mass

Want limiting reagent → need to know moles → convert to moles

$$2.00\text{ g S.A.} \times \frac{1\text{ mol S.A.}}{138.1200\text{ g S.A.}} = 0.0145\text{ mol S.A.}$$

$$4.00\text{ g A.A.} \times \frac{1\text{ mol A.A.}}{102.0900\text{ g A.A.}} = 0.0392\text{ mol A.A.}$$

	Need	Have
S.A.	0.0392	0.0145 *
A.A.	0.0145	0.0392

Limiting reactant is salicylic acid

Compare

$$0.0392\text{ mol A.A.} \times \frac{1\text{ mol S.A.}}{1\text{ mol A.A.}} = 0.0392\text{ mol S.A.}$$

$$0.0145\text{ mol S.A.} \times \frac{1\text{ mol A.A.}}{1\text{ mol S.A.}} = 0.0145\text{ mol A.A.}$$

b) If the actual yield is 1.86 g of aspirin what is the percent yield?

$$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{1.86\text{ g}}{2.61\text{ g}} \times 100 = 71.3\%$$ yield of aspirin

Determining theoretical yield aspirin:

1) moles aspirin formed from reaction with limiting reagent
2) Convert moles to mass (i.e. using molar mass).

$$0.0145\text{ mol S.A.} \times \frac{1\text{ mol aspirin}}{1\text{ mol S.A.}} \times \frac{180.157\text{ g aspirin}}{1\text{ mol aspirin}} = 2.61\text{ g aspirin}$$